LDW
0541
Jorg. Outfall
8/18/2015

PanGEO
INCORPORATED
Geotechnical & Earthquake
Engineering Consultants

August 18, 2015
File No. 12-137

Mr. William Ernst
Boeing Company
PO Box 3707
Seattle WA 98101

Re: **Geotechnical Recommendations**
Sheet Pile Shoring – Uplands Remediation
Jorgenson Forge Outfall
Tukwila WA

Dear Mr. Ernst,

This letter provides recommendations for the design of a sheet pile shoring (SPS) system to permit the excavation and removal of contaminated upland sediments located east of the former Jorgenson Forge Outfall (JFO) on the right bank of the Duwamish River (see Figure 1). Shoring is required for the remediation because the remediation will require a deep excavation extending as much as about 32 feet or to a final elevation of about -16 feet (NAVD 88).

INTRODUCTION

Leaking effluent from now abandoned pipes located along the northern boundary of the Jorgenson Forge property have resulted in contamination of the underlying soils near the line outfall into the Duwamish River (see Figure 2). Remediation of the shoreline segment of the outfall was completed in 2014 with the construction of a steel sheet pile cofferdam extending into the river to allow removal of contaminated sediments without affecting downstream portions of the river. Current remediation efforts, which are the focus of this report, include the removal of contaminated soil in a small approximately 45' by 25' area, immediately east of the 2014 cleanup (see Figure 2).

Similar to the 2014 remediation, cantilever steel sheet pile shoring will be used to allow the removal of contaminated soil below the adjacent upland segment of the outfall lines (see Figure 2). Specifically, the sheets that were driven for the east wall of the in-water cofferdam will be used as the west wall of the upland shored enclosure and the remaining sheets from the

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cofferdam will be driven to provide an enclosure abutting an existing steel sheet pile wall on the north (i.e. Boeing Wall 2-66). Work for the upland enclosure is scheduled for 2016.

The purpose of this report is to provide geotechnical parameters for the design of the sheet pile shoring. Because of the small footprint of the remediation, the major objective of the shoring design is to provide simplicity of construction without requiring internal or external support. Major design elements of the shoring system include:

- **West Wall** – Existing AZ 38-700 sheets that were previously driven along the shoreline as part of a cofferdam that allowed removal of contaminated sediments in the Duwamish during the summer of 2014. The top elevation of the existing sheets is about 12.5 feet (NAVD 88).

- **South, East, and Northwest Walls** – AZ 38-700 sheets, formerly from the offshore cofferdam that will be reused for the uplands shoring system.

- **North Wall** - The north wall will include the existing Boeing Wall 2-66 which was constructed using WZ 75 sheets. Because the WZ 75 sheets are much lighter and weaker than the AZ 38-700 sheets, the shoring design includes provisions to temporarily excavate soil behind Wall 2-66 down to the groundwater table (approximate elevation of +5 feet (NAVD 88)) to avoid overstressing the wall during the deeper site excavations.

- **Seepage Control** – Because a mechanical interlock can't be made to connect the new sheets to the existing Wall 2-66 sheets, 2 foot diameter augercast piles or drilled shafts will be drilled to a depth of 40 feet and backfilled with lean concrete to control seepage into and out of the shoring enclosure

- **Excavations in the Dry and Wet** – Excavations can be conducted in the dry within the SPS enclosure to the level of the water table (Elev. +5 feet (NAVD 88)) without overstressing the existing or new sheet pile walls. However, limited excavations can be conducted in the dry below this elevation provided that the soil behind Boeing Wall 2-66 is excavated to the water table and that continuous strengthening elements (bands) are installed at the top of Wall 2-66 to provide additional restraint. These provisions, along with monitoring the deflection of Wall 2-66, should allow excavation in the dry to extend to about elevation -4 feet (NAVD 88). The excavation, however, will require groundwater removal with internal sumps and pumps.

- **Excavations in the Wet** – Excavations extending deeper than about elevation -4 feet will need to be conducted within a flooded enclosure that maintains the water surface at about elevation +10 feet during the excavation and backfilling. Steady state water loss within the enclosure during excavation is estimated at about 80 gpm based on prior

experience with the 2014 excavation. Pumps with higher capacities should be used considering the rate at which material is removed from the enclosure.

- **Load Restrictions** – Crawler cranes and soil stockpiles must maintain a minimum clearance of 20 feet from the top of the Wall 2-66 and 10 feet from the AZ 38 sheets. Trucks should maintain a clearance of 10 feet from all walls.

SUBSURFACE CONDITIONS

Subsurface conditions underlying the site were inferred from the results of existing borings drilled at the approximate locations shown on Figure 2. Based on these explorations, the subsurface conditions at the site may include 10 feet of gravelly sand fill with concrete rubble overlying Duwamish alluvial sediments consisting of medium dense to dense, silty sands that extend to depths in excess of 80 feet. Logs of nearby borings are presented in Figures 3 thru 5.

Concrete footings and timber piles are also to be expected in the site excavations. Specifically, a large concrete pile cap and timber piling exist on the Boeing property at the northeast corner of the sheet pile enclosure. This obstruction may need to be removed if conflicting with the new construction.

Sheet piles that were driven for the Boeing contaminant wall (Wall 2-66) encountered some obstructions at the northwest corner of the wall in the area between borings PL2-030C and PL2-008C as shown on Figure 2. These obstructions, which were encountered at a depth of about 48 feet, were presumed to be logs (Roy F. Weston, 1995). The WZ 75 sheets driven for the wall could not penetrate the obstructions and were terminated short of design depth.

Groundwater in the upland area is generally present at about elevation 5 to 6 feet (NAVD 88) or about 10 to 11 feet below the ground surface. The groundwater surface is expected to be depressed near the shoreline and fluctuate with the tide levels.

DESIGN & OPERATIONAL CONSTRAINTS

Design recommendations for the cofferdam were developed for the following constraints to avoid internal bracing or external restraint of the cofferdam:

- **Top Wall Elevation**:

Wall 2-66:	+14 feet (NAVD 88)
AZ 38-700 Sheets:	Min. +12.5 feet (NAVD 88) Max. +18 feet (NAVD 88)

- **Boeing Excavation**: Any mass excavation below +5 feet will require temporary removal of soil behind Wall 2-66 on the Boeing property to elevation +5 feet to reduce lateral earth pressures on sheets in Wall 2-66.

- **Surcharge**: No crane loads permitted within 10 feet of the AZ 38-700 sheets and 20 feet of the Wall 2-66 sheets.

- **Internal Flooded Water Surface**: During contaminant excavation and backfilling below elevation -4 feet (NAVD 88) maintain water surface within the shoring at elevation +10 feet (NAVD 88); that is, excavation and backfilling below elevation -4 feet must be conducted in the wet. Steady state water loss within the "flooded" shoring is estimated at about 80 gpm exclusive of the rate of soil removal. Pumps with higher capacities (i.e. 600 gpm trash pumps, preferably with inlets in the Duwamish River) should be used considering the rate of internal soil removal. Pumps may be turned off when backfill reached elevation -4 feet (NAVD 88). Backfill placed above elevation -4 feet may require pumping and treating water from the shored excavation to avoid water overtopping the sheets.

LATERAL EARTH PRESSURES

The following lateral earth pressures are recommended for the design of the shoring, assuming a static water table at +5 feet (NAVD 88) outside the sheets and a "flooded" water surface of +10 feet (NAVD 88) inside the sheet for internal excavations and backfilling extending below -4 feet:

- Active Earth Pressure:
    - 35 pcf (Top wall or ground surface to water table at El. +5')
    - 17 pcf (Effective equivalent unit weight below water table at El. +5')
- Passive Earth Pressure:
    - 300 pcf (Effective equivalent unit weight with a factor of safety of about 1.3)

Recommended pressure diagrams for the WZ 75 sheets (Wall 2-66) and the AZ 38-700 sheets are presented in Figures 6 and 7, respectively.

WALL ANALYSES

Analyses were conducted of the existing Wall 2-66 and the AZ 38-700 sheets of the new shoring to establish maximum cut depths for internal excavations that may accomplished in the dry and as well as to determine other conditions that would need to be satisfied, such as external

excavations or internal flooding of the shoring, to allow internal excavation to reach the required depth without the need for internal bracing. All analyses were conducted using the CivilTech Shoring Suite computer program and the lateral earth pressures presented in Figures 6 and 7. The results of the analyses, which are presented in Appendix A, include the following:

- Wall 2-66
    - Can accommodate internal excavation to water table (i.e. El. + 5 feet) with about 1 inch of inward deflection
    - Excavations lower than El. +5 feet will require soil removal on the Boeing property to elevation +5 feet or the groundwater table, whichever is higher. The base of the excavation should to extend at least 10 feet behind Wall 2-66.
    - With external excavation on the Boeing Property to El. +5 feet, the internal excavation may extend to El. -4 feet without overstressing the wall. At this elevation, the deflection of Wall 2-66 may be on the order of 1.5 inches.
    - Excavations extending below about El. -4 feet will require internal flooding of the shoring (i.e. excavation in the wet). The required water surface elevation in the flooded condition at El. +10 feet is controlled by the AZ 38 700 sheets. With the flooding of the enclosure, the Wall 2-66 sheets will experience less than ½ inch deflection into the Boeing property at the target depth of the required contaminant removal.
- AZ 38 700 Sheets
    - The AZ 38 700 sheets can accommodate internal excavations in the dry to about El. -4 feet with an estimated top displacement of about 3 inches. Wall 2-66 controls the depth of internal excavation in the dry.
    - The AZ 38 700 sheets will require flooding of the enclosure with a water surface within the enclosure at El. +10 feet to accommodate excavations to the target depth of the required contaminant removal. That is, the AZ 38 700 sheets control the maximum depth of the excavation and the level of the flooding within the excavation. At the maximum depth of the excavation (-14 feet), the deflection at the top of the AZ 38 sheets is estimated at about 4 inches.

CONSTRUCTION DETAILS

WALL 2-66 EXCAVATION AND BACKFILL

Excavation behind Wall 2-66 will extend to elevation +5 feet (NAVD 88) or the water table if encountered at a higher elevation. The base of the excavation must extend 10 feet from the wall and the side slopes of the excavation may be inclined at 1(H):1(V). All material from the excavation is clean sand and gravel that may be stockpiled on the Boeing property and reused as backfill.

All backfill placed in the excavation should have loose lift heights no greater than 12 inches and each lift should be compacted with a double drum walk behind roller or a large sled compactor (>500 lbs.) or a Ho-Pac, to a dense and unyielding condition or to 95% of the material's Modified Proctor maximum dry density. Surfacing should include a minimum of 6 inches of Crushed Surfacing Base Course (WSDOT 9-03.9(3) compacted to 95% of the material's Modified Proctor maximum dry density. The pavement section should include a minimum of 2½ inches of HMA.

DRILLED SHAFTS

Two 24-inch diameter drilled shafts with lean concrete backfill will be required at each closure where the AZ 38-700 sheet meet the existing sheets of Wall 2-66. The shafts should be drilled to provide a minimum 6" overlap. Each shaft shall be drilled to a depth of 40 feet below the existing ground surface and backfilled with lean concrete (CalPortland Mix 1420 or an approved equivalent) using a tremie pipe. The shafts shall be drilled as close as possible to Wall 2-66 with the intent of removing soil close to the sheets. Casing will be required for the installations. All shafts shall be drilled to a depth of 40 feet. Shaft installations will likely occur over 2 days to allow partial curing of the primary shafts at each intersection. Contractors capable of completing the shaft installations include McDowell Northwest (425.251-8570).

WALL 2-66 STRENGTHENING

The site excavations may result in deflections of up to about 3 inches at the top of Wall 2-66, which may create high demands on the strength of the interlocks of the sheets. Accordingly, we recommend welding continuous steels bands at the tops of the sheets to improve lateral restraint and reduce wall deflection.

EXCAVATION BACKFILL

WSDOT Gravel Borrow (9-03.14(1) may be used as backfill for the excavation. The majority of the backfill will be placed in the wet without compaction. However, backfill placed within

the shoring enclosure above elevation +10 feet (NAVD 88) should have loose lift heights no greater than 12 inches and each lift should be compacted with a double drum walk behind roller or a large sled compactor (>500 lbs.) to a dense and unyielding condition or to 95% of the material's Modified Proctor maximum dry density.

MONITORING

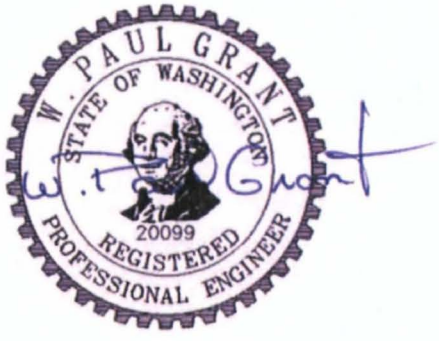
The site contractor should install survey monitoring points at the top of the sheets at the corners and midpoints of the individual wall segments. Initial readings should be taken by the contractor after installing the AZ 38-700 sheets and exposing the Wall 2-66 sheets. Subsequent readings should be obtained on a weekly basis during excavation and backfilling to confirm the adequate performance of the walls.

ADDITIONAL SERVICES

PanGEO should be present during the driving of the sheet piles to confirm subsurface conditions and assess potential actions that may be needed in the event that obstructions are encountered. We also recommend that PanGEO be present on a full time basis during excavations below +5 feet and backfilling to confirm that wall deflections are within the design predictions. During excavation, PanGEO will monitor wall movements using string lines to monitor deflection on a real time basis. Deflections approaching design values may require quick remedial action, such as halting excavations in the dry or increasing water surface levels during excavations in the wet, to maintain the integrity of the walls.

We trust that the above addresses your needs at this time. Please call with any questions on this report.

Sincerely,



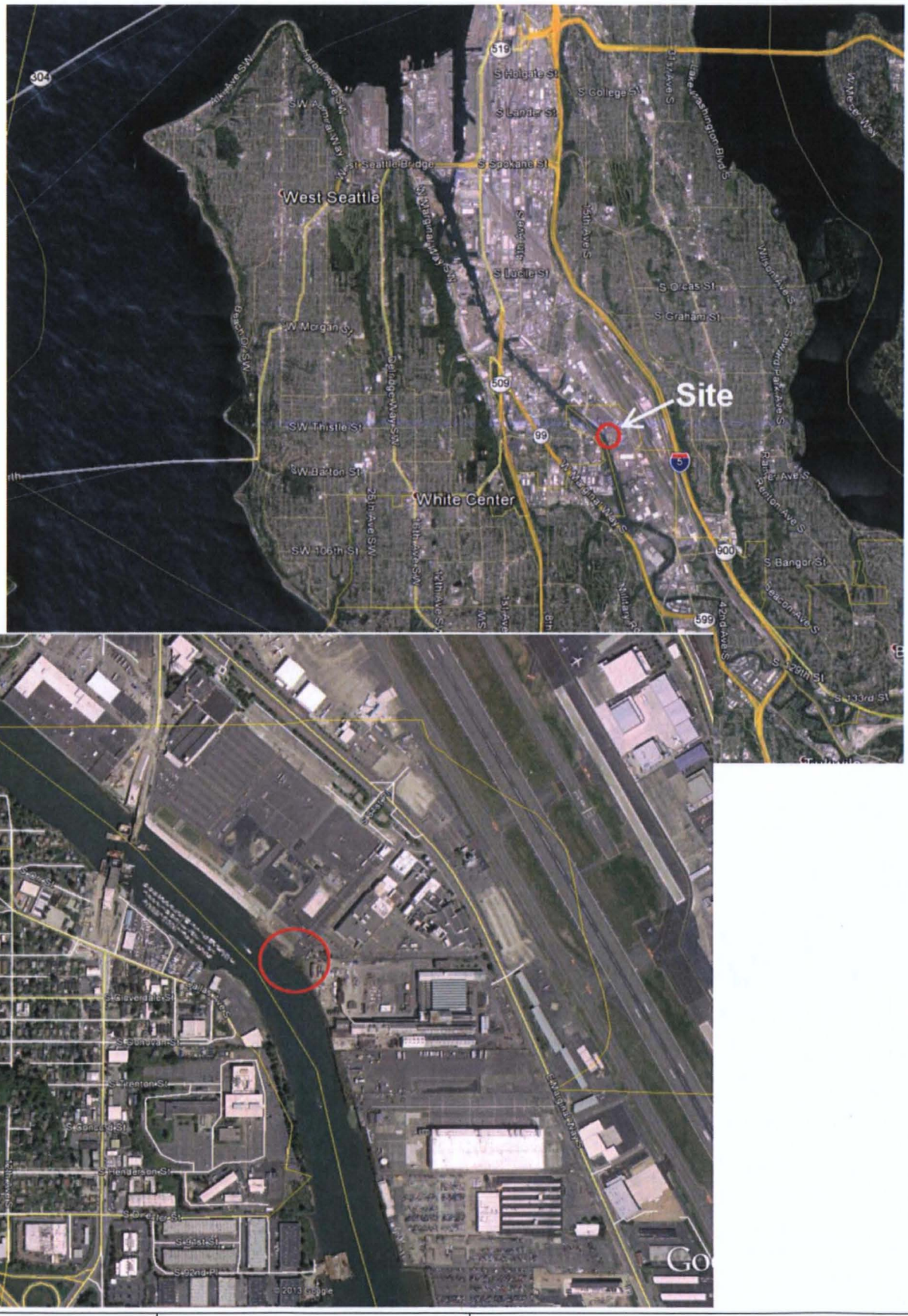
W. Paul Grant, P.E.
Principal Geotechnical Engineer

Enclosures:
Figure 1 – Vicinity Map
Figure 2 – Site and Exploration Plan
Figure 3 – Log of Boring PL2-JF01C
Figure 4 – Log of Boring PL2-303C
Figure 5 – Log of Boring PL2-008C
Figure 6 – Wall 2-66 Lateral Earth Pressures
Figure 7 – AZ 38-700 Wall Lateral Earth Pressures

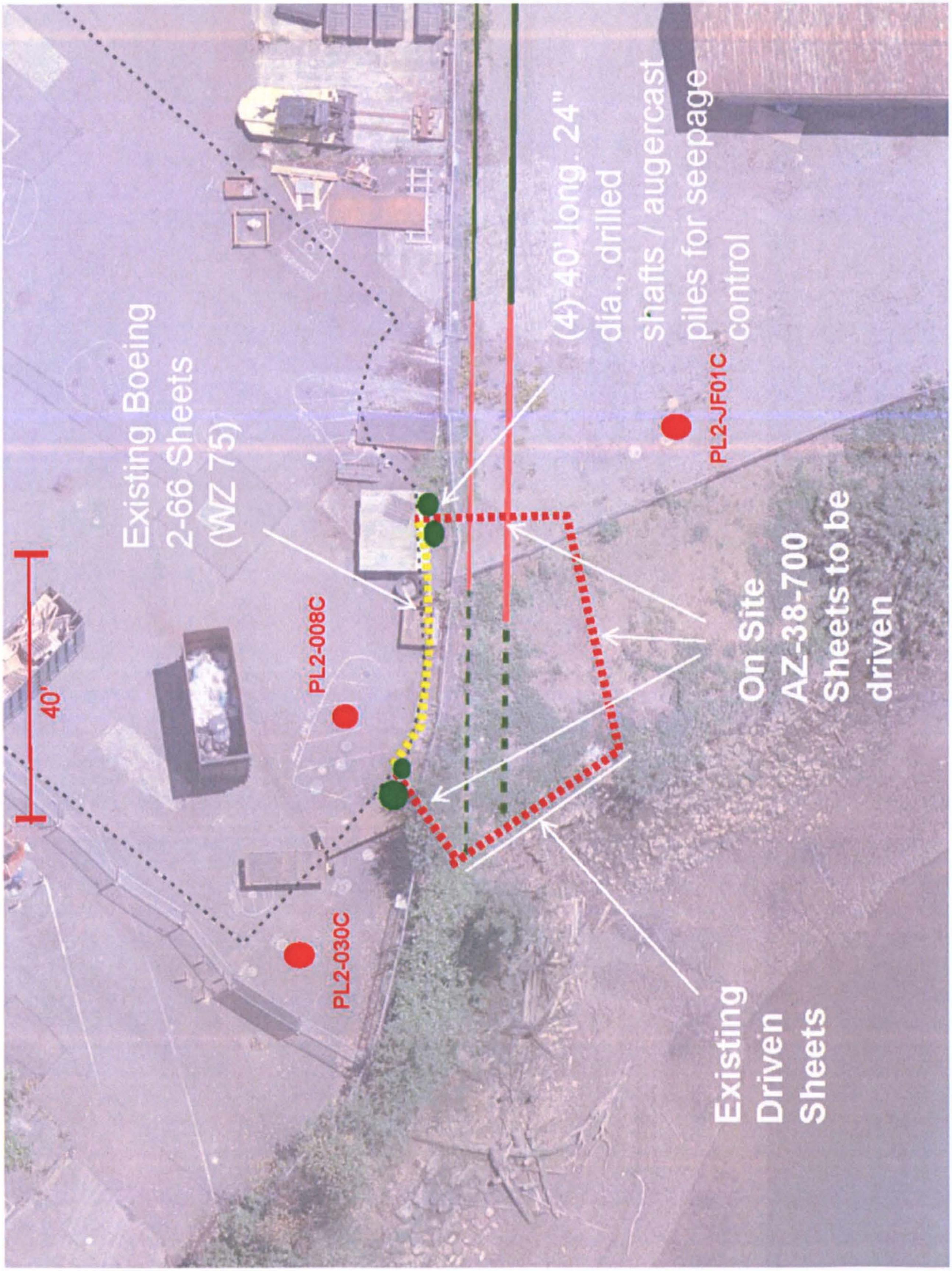
Appendix A – Shoring Wall Calculations

REFERENCES

Weston, Roy F, 1995, Construction completion report, interim corrective action, Buildings 2-10 and 2-66, Boeing Plant 2, Seattle/Tukwila, Washington: Report to the Boeing Company, February



PanGEO INCORPORATED	Source Control Action Jorgensen Forge Outfall Seattle, Washington	VICINITY MAP	
		Project No. 12-137	Figure No. 1



PanGEO INCORPORATED

Source Control Action
Jorgensen Forge Outfall
Seattle, Washington

SITE AND EXPLORATION PLAN

Project No.	Figure No.
12-137	2

MONITORING WELL PL2-JF01C

PROJECT Boeing - Plant 2
DATE COMPLETED 9 May 2001
DRILLING METHOD 8" OD HSA - GeoTech Explorations
SAMPLING METHOD 2" OD Split Spoon, 140lb Hammer
TOP OF CASING
GROUND SURFACE ELEV
LOGGED BY D. Dinkuhn - WESTON

Depth (ft)	PID Reading (ppm)	Blows Per Foot	Sample Recovery	Graphic Log	USC Classification	Lithological Description
0					GW	Sandy GRAVEL, (GW), brown, moist, (fill).
5					SP	SAND, (SP), greyish brown, fine to medium grained, trace pebbles, loose to medium dense, damp to wet, silt interbeds, (alluvium)
10						
15						
20						
25						
30						
40						
45						
50						
55					ML	Sandy SILT, (ML), brown, 80% silt, 20% fine sand, wet, (alluvium)
60	0.0	72			SW	SAND, (SW), grey, fine to medium grained, wet, no odor or sheen, (alluvium)
65	0.0	64				SAA
70	0.0	51				SAA
75	0.0	33			SM	Silty SAND, (SM), grey, fine sand, wet, no odor or sheen, (alluvium).
80	0.0	13			ML	Sandy SILT, (ML), grey, fine sand, wet, no odor or sheen, (alluvium).
90						BOH @ 81.5 feet bgs

Well Construction

- Flush mounted steel well monument and locking cap
- Concrete surface seal
- 5/17/01
- Bentonite grout well seal
- 2" well casing schedule 40 PVC
- Filter pack #10/20 RMC sand
- 2" PVC 0.01" slotted prepack well screen
- 2" threaded endcap

Notes:
BOH = Bottom of hole
SAA = same as above
No soil samples were collected for laboratory analysis.
Lithology for 0 to 60 feet taken from PL2-JF01B log.

PLATE

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Fig. 3

MONITORING WELL PL2-030C

WESTON MANAGERS DESIGNERS CONSULTANTS

PROJECT Boeing - Plant 2
DATE COMPLETED 28 March 2001
DRILLING METHOD 8" OD HSA - Cascade Drilling
SAMPLING METHOD 3" OD Split Spoon, 300lb Hammer
TOP OF CASING
GROUND SURFACE ELEV
LOGGED BY K. Broom - WESTON

Depth (ft)	PID Reading (ppm)	Blows Per Foot	Sample Recovery	Graphic Log	USC Classification	Lithological Description
0						4" Asphalt
					GW	Gravelly fill
5					SW	Gravelly SAND, (SW), light greyish brown, 85% medium sand, 15% angular gravel, medium dense, dry, (fill).
10					SP	SAND, (SP), brown, 100% medium sand, moist to wet.
35	2.2	42			SW	SAND, (SW), black, fine to medium grained, wet, no odor or sheen, (alluvium).
40	5.4	29				SAA, scattered roots.
45						No recovery.
50	3.7	37				SAA, no roots.
55						No recovery.
60						No recovery.
65	4.6	31				SAA.
70	3.3	49				SAA.
75	2.4	15				SAA.
					SM	Silty SAND, (SM), black, wet, medium dense, no odor or sheen, (alluvium).
80	1.3	12				SAA, Silty fine SAND, scattered sea shells.
						BOH = 81.5 feet.
85						

Well Construction

- Flush mounted steel well monument and locking cap
- Concrete surface seal
- 4/23/01
- Bentonite grout well seal
- 2" well casing schedule 40 PVC
- Filter pack #10/20 RMC sand
- 3.5" PVC 0.01" slotted prepack well screen
- 2" threaded endcap

Notes:
BOH = Bottom of hole.
SAA = Same as above.
No soil samples were collected for laboratory analysis.
Lithology for 0 to 20 feet taken from PL2-030A log.

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PLATE A-4

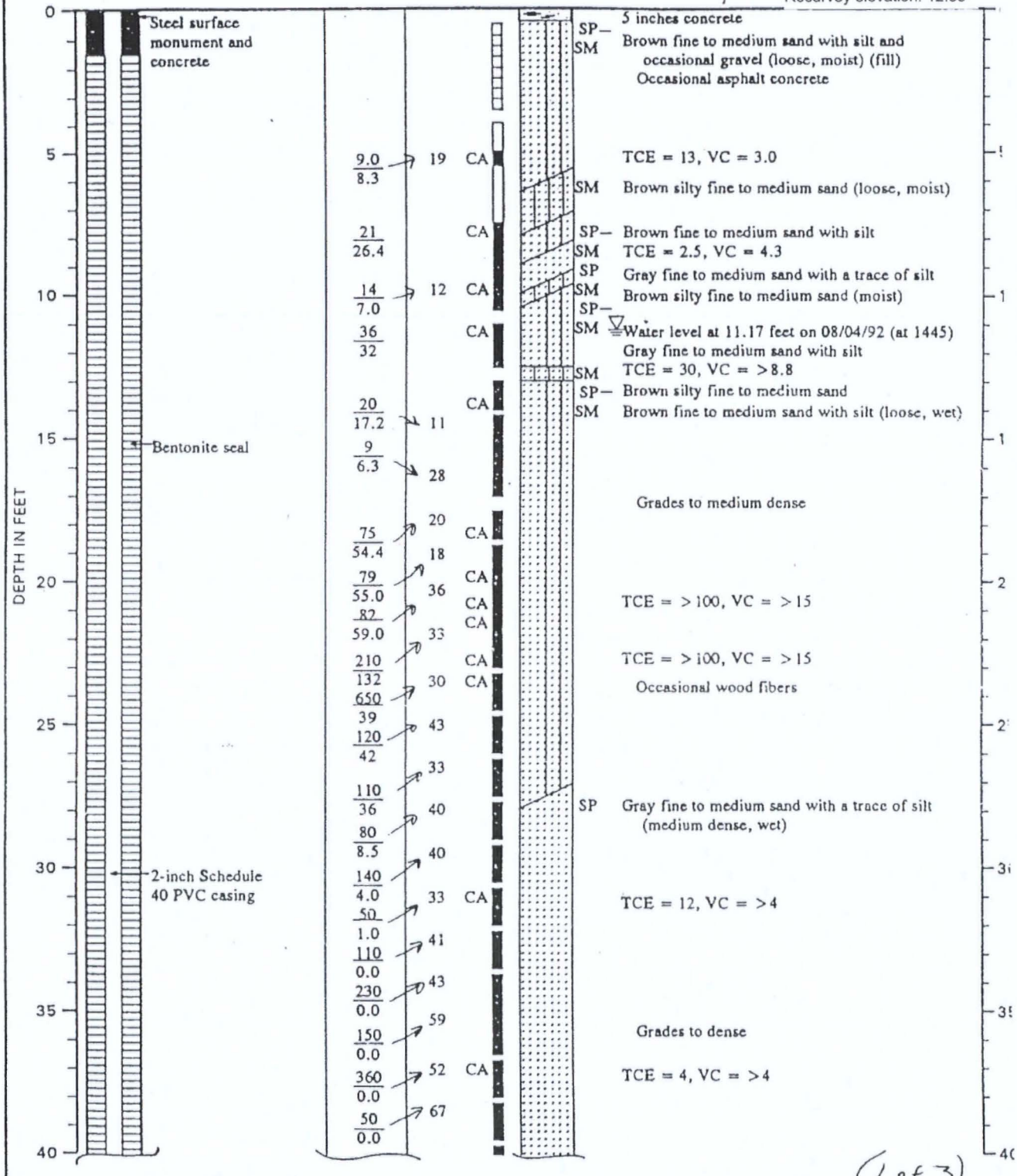
Fig. 4

MONITORING WELL PL2SW-MW8C

PL2-008C

WELL SCHEMATIC

Casing Elevation (ft.): 12.47
Casing Stickup (ft.): -0.36



Note: See Figure A-2 for explanation of symbols
See Figure A-35 for explanation of typical deep 2-inch diameter monitoring well construction

(1 of 3)

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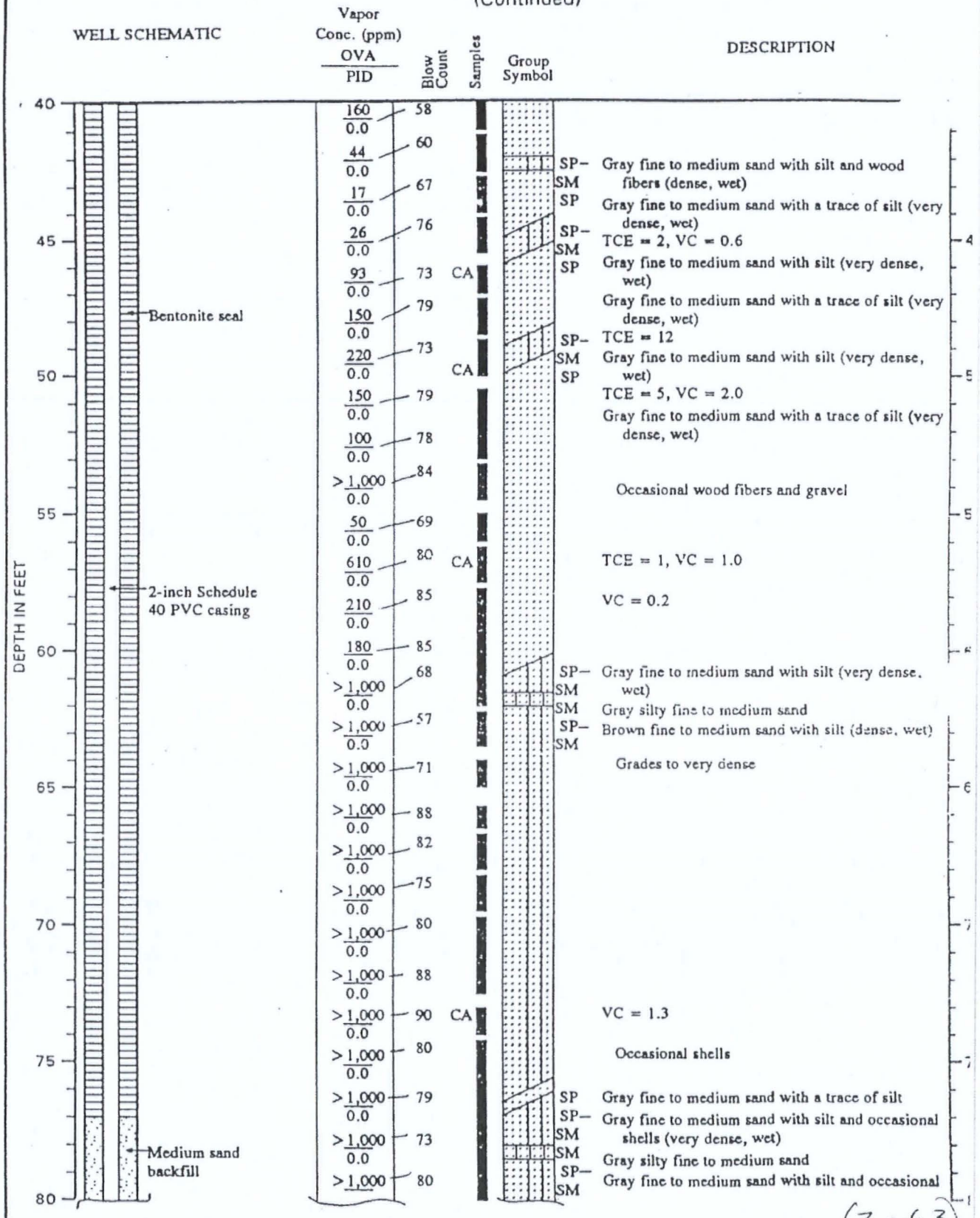
LOG OF MONITORING WELL

FIGURE A–10a

Fig. 5
sheet 1 of 3

MONITORING WELL PL2SW-MW8C
(Continued)



Note: See Figure A-2 for explanation of symbols
See Figure A-35 for explanation of typical deep 2-inch diameter monitoring well construction

(2 of 3)

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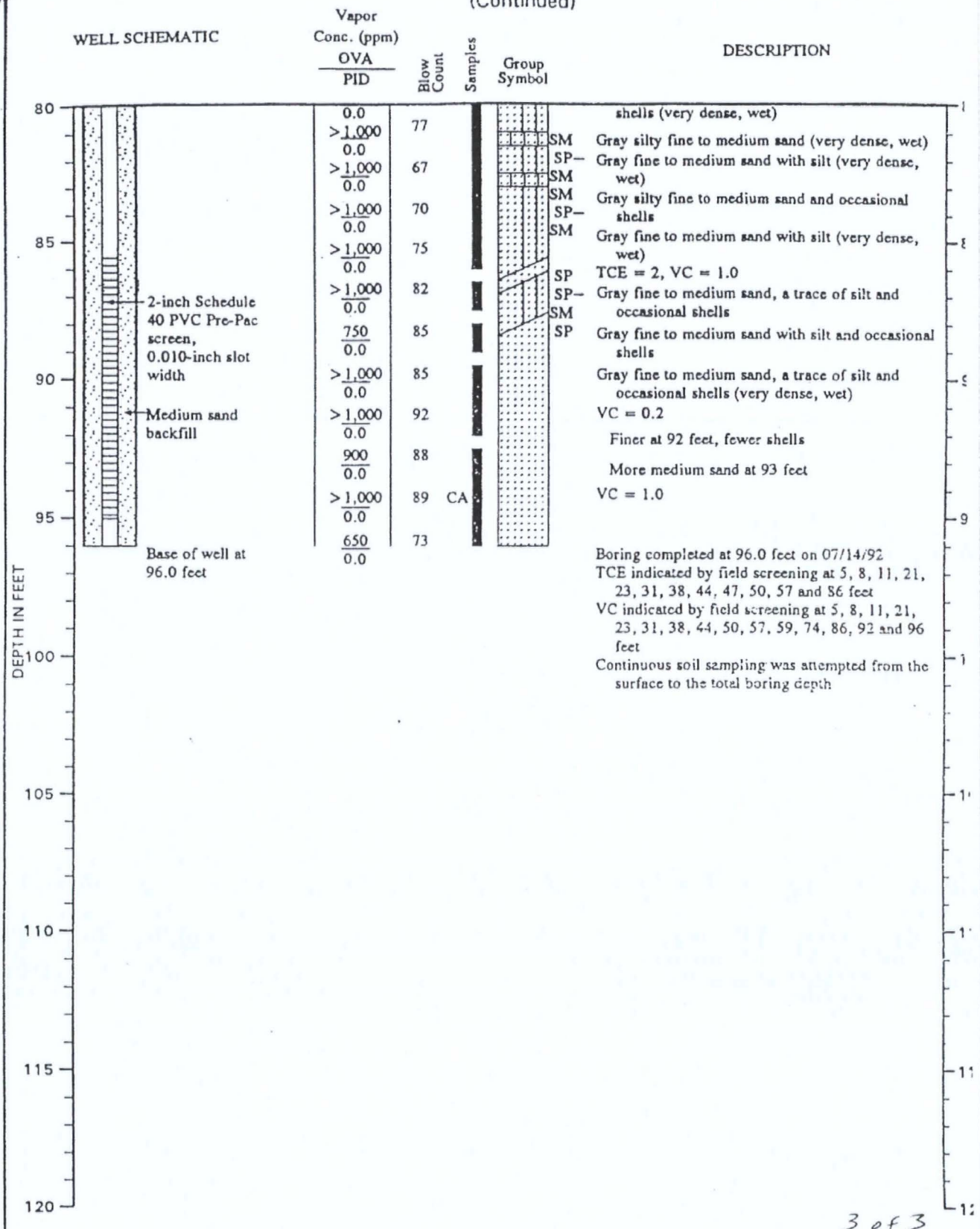
LOG OF MONITORING WELL

FIGURE A-10b

Fig. 5
Sheet 2 of 3

MONITORING WELL PL2SW-MW8C
(Continued)



Note: See Figure A-2 for explanation of symbols
See Figure A-35 for explanation of typical deep 2-inch diameter monitoring well construction

3 of 3

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LOG OF MONITORING WELL

FIGURE A-10c

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Sheet 5
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